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ORIGINAL ARTICLE

Limitations of Structural Allograft in Revision Total Knee Arthroplasty

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Abstract Management of large bone defects in total knee arthroplasty (TKA) usually has involved modular prostheses with metal augments, structural allografts, and megaprostheses. We retrospectively reviewed the outcome of treatment of major bone defects for 74 patients (79 knees) who had revision TKAs with structural allografts; nine patients were lost to followup before 5 years, leaving 65 patients (70 knees, or 88%) followed for a minimum of 5 years or until revision or death. Medical records, radiographs, patient surveys, and correspondence were used for all data. Sixteen patients (22.8%) had failed reconstructions and underwent additional revision surgery; eight of the 16 were secondary to allograft failure, three were secondary to failure of a component not supported by allograft, and five were secondary to infection. In patients not requiring revision surgery, the Knee Society score improved from 49 preoperatively to 87 postoperatively. We observed revision-free survival of 80.7% (95% confidence interval, 71.7–90.8) at 5 years and 75.9% (95% confidence interval, 65.6–87.8) at 10 years. Our data support the selective use of structural allograft for large cavitary defects encountered during TKA. However, the rates of complications and reoperations suggest efforts to improve results or develop more durable alternative methods are warranted for these challenging reconstructions.
Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

One of the major challenges sometimes encountered in revision TKA is management of large bone defects. Bony defects can be treated with numerous techniques ranging from cancellous bone graft, bone cement, and small metal augments for smaller defects to large metal augments, megaprostheses, and structural allografts for larger defects [3–5, 7, 11, 12, 16].

The potential advantages of structural allograft are restoration of bone stock, biocompatibility, and the ability to shape the allograft to the defect. Conversely, allografts have potential disadvantages such as possible nonunion, resorption, fracture, prolonged surgical time, potential for disease transmission, and an increased susceptibility to infection [2, 6, 10, 12, 16, 17]. Reports of nonunion range from 0% to 4% and rates of infection range from 0% to 10% [1, 2, 8, 10]. Revision TKA with structural allograft makes use of femoral heads, bulk tibia, or bulk distal femoral allografts to achieve mechanical stability for the implants. These grafts with their prolonged healing time and potential for resorption are best stabilized with long stem components and frequently require adjunctive fixation for stabilization of the graft.

To confirm earlier reports we therefore determined the revision-free survival, reasons for failure, clinical outcomes, radiographic characteristics, and complications of cemented revision TKA with structural allografting for large bone defects at a minimum 5-year followup.

Materials and Methods

We queried our institutional total joint registry for patients who underwent TKA with structural bone grafting for reasons other than a tumor between January 1, 1985, and January 1, 2001. We identified 94 patients (99 knees). Patients undergoing primary arthroplasties or those receiving autograft were excluded, leaving 74 patients (79 knees) undergoing revision TKA with structural allograft. Of the 74 patients, two had bilateral procedures and three had repeat TKA with structural allografting after failure of a previous structural allograft. Nine patients had functioning implants with grafts in place but were lost before 5 years followup leaving 65 patients (70 knees). Eleven of these patients died before 5 years followup, with weighted data for these patients included to calculate survivorship curves. The average patient age was 67.9 years with an average of 2.5 procedures before the allograft revision TKA. The most common reason for revision was aseptic loosening followed by periprosthetic fracture and infection. The most common original underlying diagnosis was osteoarthritis followed by posttraumatic arthritis and rheumatoid arthritis (Table 1). Forty patients (43 knees or 54%) were alive and had intact implants at a minimum 5-year clinical followup (mean, 90 months; range, 60–178 months).

Table 1. Patient demographics

Demographic	Number
Average age	67.9 years (range, 34–87 years)
Average number of procedures	2.5 (range, 1–10)
Gender	
Male	37
Female	28
Side	
Left	37
Right	33
Underlying diagnosis	
Osteoarthritis	43
Posttraumatic	14
Rheumatoid arthritis	1
Juvenile rheumatoid arthritis	2
Osteogenesis imperfecta	1
Reason for revision	
Aseptic failure	53
Infection	6
Component fracture	2
Nonunion	1
Periprosthetic fracture	8

We typically used structural allograft as an option in the treatment of more severe AORI Types 2b and 3 defects using the Anderson Orthopaedic Research Institute (AORI) bone defect classification proposed by Engh and Ammeen [7] (Fig. 1). All patients had either Type 2b or 3 defects. We used 87 fresh-frozen structural allografts in 70 revision cemented arthroplasties (Table 1). Structural allografting was used in the tibia in 27%, the femur in 49%, and in the femur and tibia in 24% (Table 2).

We reviewed the medical records, radiographs, patient surveys, and correspondence to determine outcomes. No patients were seen in followup specifically for this study, but were followed as part of routine clinical surveillance at our institution. We measured patient clinical outcome using the Knee Society score (Insall modification) recorded preoperatively and at the last followup [13]. Forty living patients had 43 revision-free knees and had clinical followup at a minimum of 5 years. Patients requiring repeat or revision surgery were defined as having failed results.

Adequate standing anteroposterior and lateral radiographs were available for 32 of the 42 patients (33 knees) at 5 years followup. We (RDB, DGL) analyzed these films using the Knee Society Roentgenographic Evaluation and Scoring System [9]. We specifically evaluated radiographs for allograft-host union and for progressive radiolucencies suggestive of loosening.

Survivorship analysis was performed using Kaplan-Meier survivor curves and 95% confidence limits were identified at 5 and 10 years followup [14].

Results

We observed a revision-free survival of 80.7% (95% confidence interval, 71.7–90.8) at 5 years and 75.9% (95% confidence interval, 65.6–87.8) at 10 years (Fig. 2). When revision secondary to allograft failure alone was considered, the 5- and 10-year survival rate was 87.4% (Fig. 3).

Sixteen patients underwent revision for failed reconstructions. The average time to failure was 42 months (range, 1–68 months) (Table 3). Five failures occurred secondary to infection, comprising 7.1% of the study group. Two of these patients had a history of infection, two had local wound problems at the time of revision surgery requiring muscle flap or skin grafting, and two required above-knee amputation as definitive treatment. Two of the infected revisions contained large segment bulk allograft, two contained femoral head allograft, and one contained femoral head and segmental allograft. Of these 16 failures, eight related to the allografts. Seven of the failures were

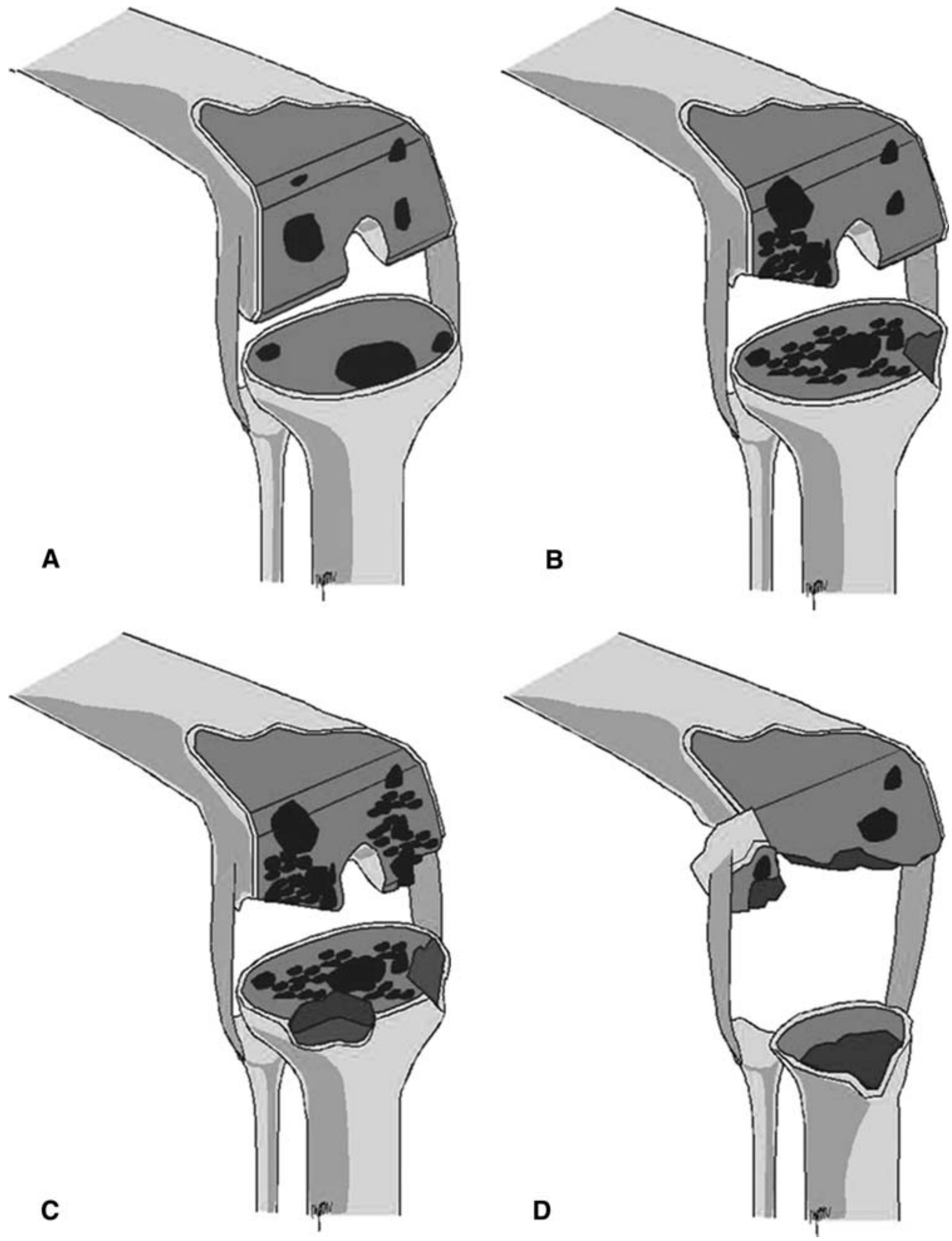

Fig. 1A–D (**A**) Anderson Orthopaedic Research Institute (AORI) Type 1 deficiency has intact metaphyseal bone. (**B**) A Type 2a deficiency involves metaphyseal deficiency of only one condyle or plateau, and (**C**) a Type 2b deficiency involves metaphyseal deficiency of both condyles or plateaus. (**D**) A Type 3 deficiency has massive cavitary defects with severe metaphyseal deficiency. (Reprinted with permission from Mulhall KJ, Ghomrawi HM, Engh GA, Clark CR, Lotke P, Saleh KJ. Radiographic prediction of intraoperative bone loss in knee arthroplasty revision. *Clin Orthop Relat Res.* 2006;446:51–58.)

Table 2. Distribution of allografts in the study population

Structural allograft	Number
Femoral allografts	50
Femoral head	33
Allograft prosthetic composite femur/bulk distal femur	17
Tibial allografts	37
Femoral head	30
Allograft prosthetic composite tibia/bulk tibia	7

complications secondary to resorption, including instability, implant loosening, and component failure. Only one patient had allograft nonunion and subsequent rerevision was needed at 42 months (Fig. 4). Of the eight allograft failures, three occurred with large segmental allografts and were secondary to allograft nonunion, allograft fracture, or knee dislocation secondary to allograft resorption. Five failures occurred in the smaller femoral head allografts and all of these were secondary to resorption (Fig. 5). At 30 months followup, the patient had allograft resorption with subsequent tibial tray fracture. Three nonallograft failures occurred secondary to tibial loosening in two patients and patellar loosening in one; all allografts in these cases were intact, united, stable, and did not require replacement or revision at the time of revision surgery.

For the 40 patients with a minimum 5-year followup, the average postoperative Knee Society score was 87 (range,

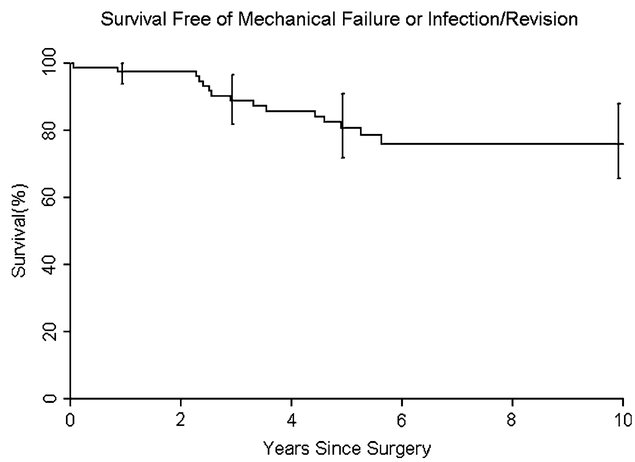

Fig. 2 The Kaplan-Meier 5- and 10-year survivorship rates with revision for any reason were 80.7% (95% confidence interval, 71.7–90.8) and 75.9% (95% confidence interval, 65.6–87.8), respectively.

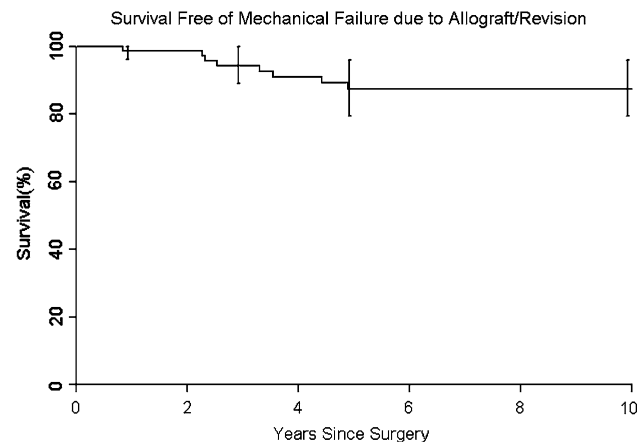

Fig. 3 The Kaplan-Meier 5- and 10-year survivorship rates with revision secondary to allograft failure only were 87.4% (95% confidence interval, 75.9–96.1) and 87.4% (95% confidence interval, 75.9–96.1), respectively.

37–100) compared with 49 (range, 0–84) preoperatively. The average range of motion (ROM) increased from 73° preoperatively to 101° postoperatively. Two patients had a decrease in Knee Society score compared with preoperatively.

For the 32 patients (33 knees) with adequate radiographs and minimum 5 years followup, two had progressive radiolucencies and two had asymptomatic allograft-host nonunion. The remaining 28 patients (29 knees) had no progressive radiolucencies at last followup.

Thirteen patients (13 knees) had 15 complications not requiring revision (Table 4). Two patients had ligamentous laxity develop that was treated with bracing; neither of these patients wanted a repeat operation. Two patients had a flexion contracture develop. One was treated with manipulation with improvement in ROM; the other had severe rheumatoid arthritis and declined additional treatment. Intraoperative patellar fracture occurred in two patients and intraoperative tibial fracture in one patient. These were treated adequately without internal fixation and by protected weightbearing. A superior pole of the patella fracture occurred 3 years postoperatively in one patient that healed with knee immobilizer treatment. The fracture healed and was stable intraoperatively at a future revision.

Table 3. Summary of the 16 failures requiring revision

Patient number	Reason for revision	Allograft	Allograft source	Time to failure (months)
1	Infection	APC femur	Distal femur	27
2	Infection	Femoral head	Proximal tibia	28
3	Infection	Femoral head, femoral head	Distal femur, proximal tibia	55
4	Infection	Proximal tibia	Proximal tibia	1
5	Infection	APC femur	Distal femur	11
6	Nonallograft (tibial loosening)	APC femur	Distal femur	35
7	Nonallograft (patellar loosening)	Femoral head	Distal femur	63
8	Nonallograft (tibial periprosthetic fracture)	APC femur	Distal femur	68
9	Allograft (dislocation and resorption)	APC tibia	Proximal tibia	10
10	Allograft (aseptic loosening)	APC tibia, femoral head	Proximal tibia, distal femur	53
11	Allograft (aseptic loosening of femur)	Femoral head, femoral head	Proximal tibia, distal femur	40
12	Allograft (distal femur aseptic loosening)	Femoral head	Distal femur	58
13	Allograft (aseptic loosening, instability)	Femoral head, femoral head	Proximal tibia, distal femur	124
14	Allograft (fracture femoral component)	Femoral head	Distal femur	28
15	Allograft (allograft nonunion)	Distal femur allograft	Distal femur	42
16	Allograft (fracture of tibial baseplate)	Femoral head	Proximal tibia	63

APC = allograft-prosthetic composite.

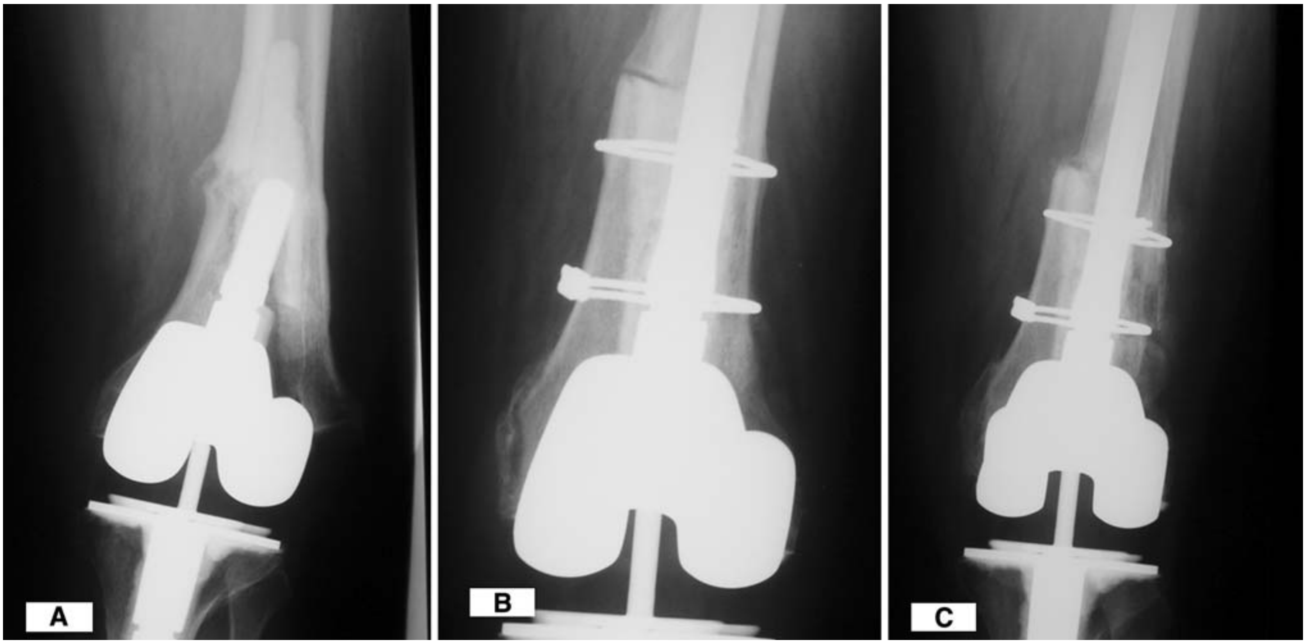

Fig. 4A–C The radiographs show (**A**) a periprosthetic femur fracture that was treated with (**B**) revision TKA using a distal femoral allograft. (**C**) The patient's radiograph 42 months after revision shows a symptomatic distal femoral allograft nonunion that underwent revision.

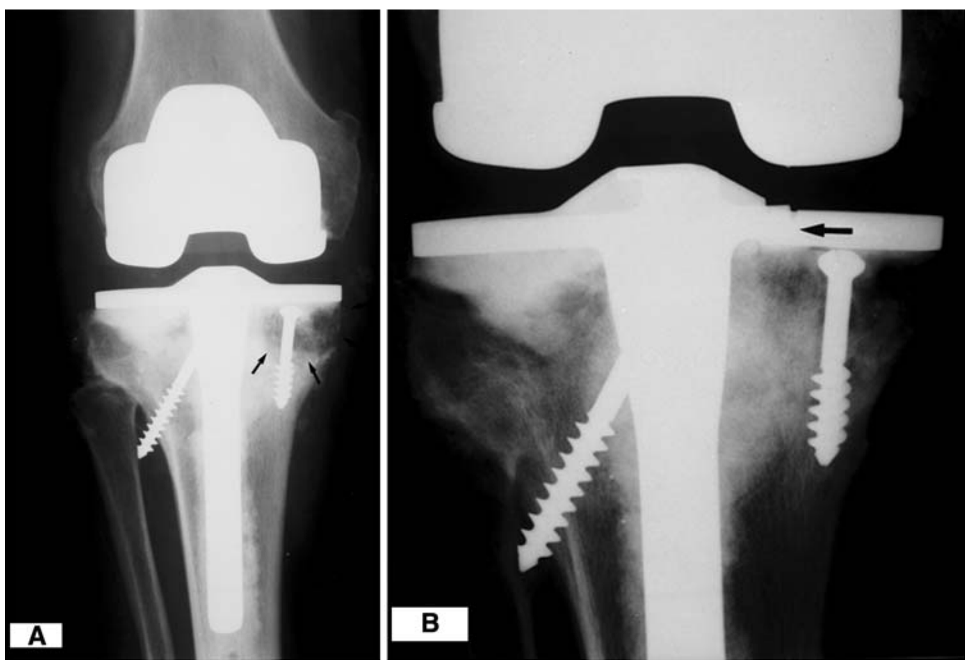

Fig. 5A–B A 63-year-old patient experienced failure secondary to allograft resorption 18 months after femoral head allografting to the tibial plateau. (**A**) Allograft resorption is evident in the medial tibial plateau. (**B**) A radiograph obtained 30 months postoperatively shows a tibial tray fracture secondary to allograft resorption. The tibial tray fracture was seen after prosthesis removal.

One patient with pulmonary embolus had no long-term complications after appropriate anticoagulation. A distal femoral stress fracture through host bone (nonallograft) occurred 2 years postoperatively and healed with a brief period of immobilization. Chronic swelling suspicious for low-grade infection developed in one patient; he currently is asymptomatic on long-term antibiotic suppression. Three patients had inadequate soft tissue coverage requiring skin grafting in one case and skin grafting with a muscle flap in two cases. The patient requiring skin grafting had an infection develop 11 months postoperatively that was treated with above-knee amputation. One of the two patients requiring muscle flap coverage who had an infection in the immediate postoperative period had an above-knee amputation. The third patient had a good result with pain relief, increased ROM, and activity level. Seven of the 15 complications occurred in patients eventually having rerevision.

Table 4. Complications of revision TKA with allograft

Complication	Number of patients
Ligamentous laxity	2
Flexion contracture	2
Patellar fracture	2
Distal femur fracture	1
Saphenous nerve hypersensitivity	1
Symptomatic hardware	1
Pulmonary embolus	1
Intraoperative fracture	1
Chronic infection/swelling	1
Inadequate soft tissue coverage requiring muscle flap	2
Inadequate soft tissue coverage requiring skin grafting	1
Total	15

For the 11 patients who died before 5 years followup, the Knee Society score had improved an average of 36 points from preoperatively to last followup. All allografts were radiographically intact at last followup, Nine additional patients were lost before 5 years followup at an average of 42 months. These patients had, on average, a 24-point increase in Knee Society score at last followup. Three of these nine patients had clinical worsening of the Knee Society score compared with preoperatively.

Discussion

Revision TKA using femoral head and larger bulk tibial or femoral allograft is a helpful method for restoration of TKA implant support in select cases of revision TKA with large bony deficits. Allograft has the potential to restore valuable bone stock while simultaneously providing immediate stability. However, structural allografting carries risks of infection, resorption, and resulting implant loosening as documented in this study. To confirm previous reports, we therefore reviewed our patients with structural allografts to determine the revision-free survival, reasons for failure, clinical outcomes, radiographic characteristics, and complications of cemented revision TKA.

We recognize certain limitations to the study. The extended study period, evolving orthopaedic implant technologies, and variable use of allografts by multiple surgeons resulted in inconsistencies in indications and techniques. Additionally, some patients were lost before 5 years followup and radiographic followup was incomplete in several patients. Followup frequently was limited to telephone questionnaires; however, their usefulness has been correlated with physician assessments (but not standardized outcome measures) [15]. Nonetheless, the relatively large patient population, length of followup, and survival data provide important insights into the potential advantages and disadvantages of this tool in reconstruction.

Our data suggest revision TKA with structural allografting has a greater than 20% rate of complications and failures with most of these directly or indirectly allograft-related. The Kaplan-Meier analysis reveals 5- and 10-year survival rates of 80.7% and 75.9%, respectively, using revision or removal as the end point. Our data appear consistent with those of others in terms of revision rates and complications (Table 5) [1, 2, 8, 10]. Clatworthy et al. [2] reported 50 patients with 52 revision TKAs with allografts at an average 8-year followup and reported a survival rate of 72% at 10 years. Twenty-five percent of the revisions failed, five secondary to resorption, four secondary to infection, two secondary to nonunion, and two secondary to clinical failure. Ghazavi et al. [10] reported 28 patients (30 knees) with massive bone loss around TKA and found failures in seven of the 30 knees. Three failures were secondary to infection, two secondary to tibial component loosening, and one each secondary to distal femoral allograft fracture, allograft-host nonunion, allograft fracture not having rerevision, and patellar tendon avulsion.

The mechanisms of failure may be influenced by allograft type. The smaller allografts in the form of femoral heads tended to have failure secondary to allograft

Table 5. Comparison of rates of complications and reoperations in TKA with structural allograft

Study	Number of patients (knees)	Average followup (years)	Reoperation secondary to infection (%)	Reoperation secondary to allograft complication (%)	Reoperation secondary to nonallograft complication (%)	Radiographic nonunion not requiring revision (%)	Complications not requiring reoperation (%)
Current study	65 (70)	7.5	7.1	11.4	4.3	6	18.6
Backstein et al. [1]	58 (61)	5.4	4.9	11.5	3.3	0	N/A
Clatworthy et al. [2]	50 (52)	8.1	8	11.5	3.8	0	N/A
Ghazavi et al. [10]	28 (30)	4.2	10	6.7	6.7	0	N/A
Engh et al. [8]	30 (35)	4.2	0	0	2.9	0	17

N/A = Not available.

resorption with subsequent loosening or component failure. Conversely, the large bulk allografts were more likely to fail secondary to infection or nonunion. Furthermore, the consequences of failure in allograft TKA are potentially devastating. Infection occurred in 6% of knees in the study population with two of five such patients requiring above-knee amputation for definitive treatment. The increased risk and consequences of infection with large structural allografts is of great concern and methods to reduce this risk while restoring structural support for the revision implant would be helpful.

In patients not experiencing complications and achieving allograft union, the results of structural allografting can be very good. On average, patients gained 28° motion and had an increase in Knee Society score of 38 points. Structural allografts appear a durable alternative with reasonable functional outcome when infection, nonunion, and resorption are avoided. One study [2] reported clinical scores improved from 32.5 preoperatively to 75.6 at the time of review. Additionally, ROM improved from 60.5° preoperatively to 88.6° at the time of review.

Our data confirm the usefulness of structural allograft for large segmental or combined segmental and cavitary lesions, which impair the mechanical stability and support for the prosthesis. Our current bias is to favor structural allografts in young patients and megaprostheses in older patients. However, the rate of complications and reoperations suggests continued efforts to improve results, explore new implant technologies, and develop more durable alternative methods are warranted.

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